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Résumé – L'imagerie de contraste est un domaine très actif dans lequel plusieurs techniques de codage d'excitation ont été proposées. Dans ce travail nous nous focalisons sur le codage continu du signal ultrasonore à transmettre au milieu à explorer. Nous montrons de façon empirique qu'il existe des valeurs particulières des paramètres fréquentiels de l'excitation de type « chirp » qui optimisent le contraste de l'image ultrasonore. Nous montrons aussi que pour des microbulles nonlinéaires que les indices de modulation ne sont plus symétriques.

Abstract – The contrast medical imaging is an active research domain in which several coding techniques of the transmit have been proposed to increase the contrast. In this paper, we focus on the continuous coding of the Ultrasound transmits, such as "chirp" sequences, and their insonation on the medium under exploration. We empirically show that there are particular values for the frequency parameters of the frequency coded excitation "chirp" which optimize the contrast in contrast enhanced ultrasound images. We also show that in the nonlinear response of micro-bubbles the modulation indices are no longer symmetrical.

Keywords: Empirical Optimization, Chirp Frequency Parameters and Contrast Ultrasound Imaging.

1. Introduction

Contrast Enhanced Ultrasound imaging (CEUS) is an imaging technique involving the flushing of a contrast agent (made up of micro-bubbles) into the bloodstream prior to examination. It is in a continuous effervescence and is applied in both blood flow and tissue harmonic imaging. The contrast imaging, i.e. the imaging of the medium infused with micro-bubbles is a diagnostic tool which cannot be discarded in any clinical routine nowadays due to its vast importance.

Recently, this field is undergoing profound changes in the way of carrying out images by encoding the ultrasound waves transmitted to the medium under exploration such as tissue etc.. The reason behind coding those "exploring" signals is to improve the contrast and tissue penetration. Several types of coding are available: continuous coding such as amplitude modulation and frequency modulation such as "chirps" and discrete coding such as impulse inversion.

In this paper we will focus on the transmission of "chirp" [1, 2, 3] and more precisely determine the optimal frequency parameters that govern the instantaneous frequency law.

2. Method

The principal of contrast coded imaging consists of transmitting, by means of an insonifying transducer, a signal (see Fig. 1) of type :

$$x(t)=exp(-(t-t_0)^2/2\sigma^2)sin((2\pi f_i(t))t), \qquad (1)$$

where the instantaneous frequency is governed by a polynomial of the form :

$$f_i(t)=f_0+\beta_1 t+\beta_2 t^2. \qquad (2)$$

After propagation in the intermediate medium towards the medium infused with micro-bubbles, a signal of non-linear properties is backscattered towards the transducer.

3. Results And Discussions

So far, the international community believes that it

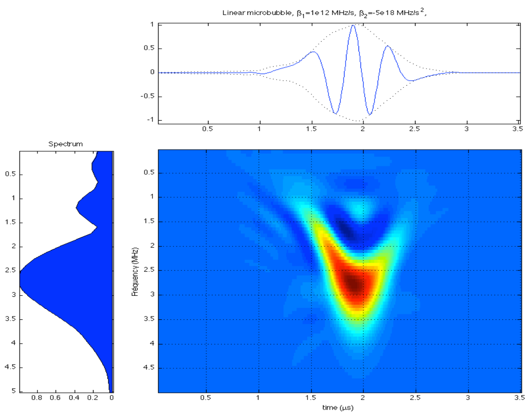

Figure 1 : Time-Frequency representation of the modulated signal transmitted to the micro-bubbles.

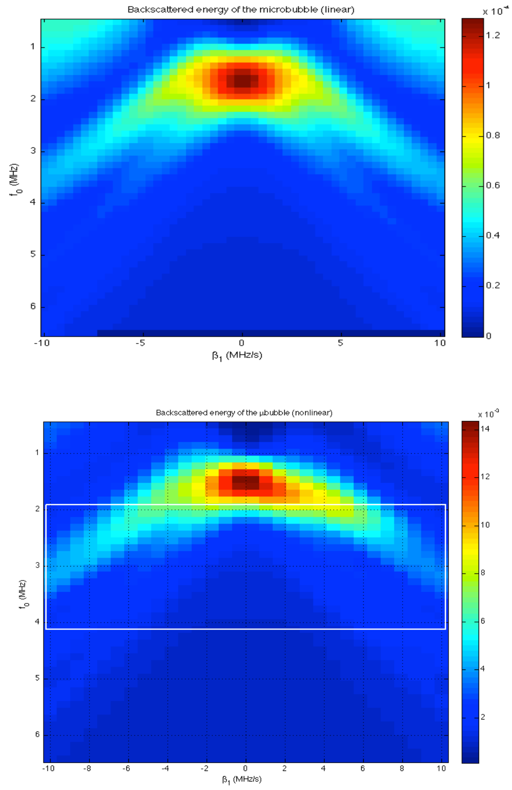

Figure 2 : Energy of the backscatter at different central frequencies and modulation indices β_1 the (top image) shows the linear response of the micro-bubbles and the (bottom image) shows the non-linear response.

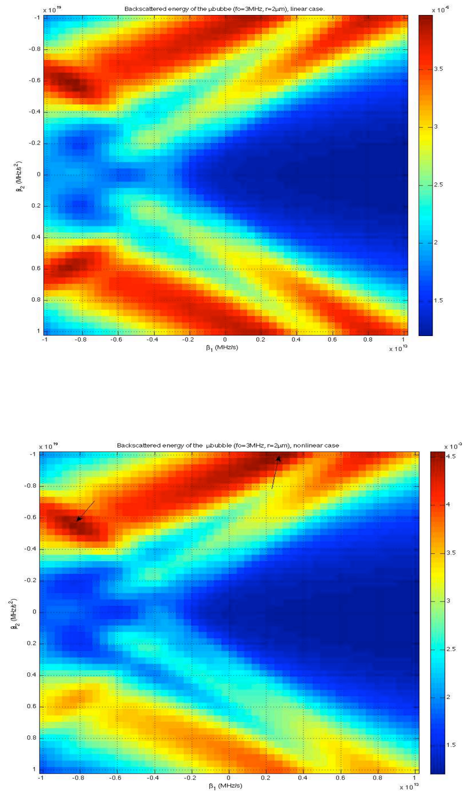

Figure 3 : Energy of the backscatter at different modulation indices β_1 and β_2 the (top image) shows the linear response of the micro-bubbles and the (bottom image) shows the non-linear response.

is enough to transmit a « chirp » (figure 1) in order to enhance the contrast in CEUS images.

In our case we will compute the energy in our way to enhance the contrast since the energy is proportional to the contrast and feasible to compute.

In this province, we show that the transmission of a « chirp » into the medium infused with micro-bubbles is not always useful especially when the central frequency of the « chirp » (given by equation (2) for β_1=0 and β_2=0), is close to the resonant frequency of bubbles (~1.5 MHz).

If the central frequency of the transducer is 3MHz and its -3dB bandwidth is 2.25 MHz, it is necessary according to figure 2 to choose ($\beta_1 \neq 0$). But if the central frequency of the transducer is 1.5 MHz and its -3dB bandwidth is 1.125 MHz, it is not necessary to frequency modulate the signal or use chirps, so we choose (β_1 =0).

We show as well in figure 2 that (β_2=0). Consequently the frequency modulation index β_1 in the linear response of the micro-bubbles does not contribute to the enhancement of the energy as the values indicated by the colorbar are so small, it merely plays this vital role in the non-linear response of the micro-bubbles where energy values are higher.

The same behavior is observed in figure 3 but for ($\beta_2 \neq 0$) and f_0=3MHz. We note that the symmetry of the modulation indices in the non-linear response of micro-bubbles is lost.

Assuming again the same value of the central frequency f_0=3MHz (and its -3dB bandwidth is 2.25 MHz), in the non-linear response of the micro-bubbles we notice that the maximum backscattered energy occurs at β_1=-0.5^{e+}12 MHz/s and β_2=-0.5^{e+}19 MHz/s^2. We notice that this solution is not unique since there exist another maximum at β_1=0.3^{e+}12 MHz/s and β_2=-1.0^{e+}19 MHz/s^2. This figure indicates that the automatic search for the optimal solution via simple gradient

algorithm will not converge to the supreme, thus other techniques should be considered.

4. Conclusion and Perspective

Our study shows that taking into account both the transducer and the size of the micro-bubble, it is necessary to investigate the frequency parameters that govern the behavior of time-frequency transmit signal to optimize the energy reflected by the medium infused with micro-bubbles and thus the contrast.

Currently we are developing a procedure capable of providing the optimal settings automatically.

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